


8/6/2010



New Water Disinfection Technology for Earth and Space Applications as part of the NPP Fellowship Research


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NASA POSTDOCTORAL PROGRAM
Administered by ORAU

KSC Engineering Academy Lecture Series
August 12th, 2010




Background

- Why do we need clean water?



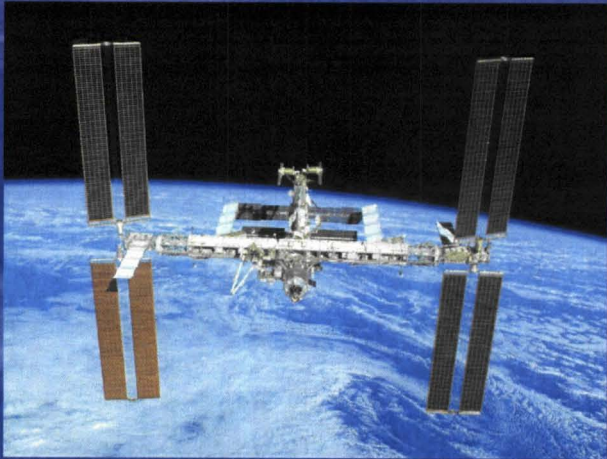
www.fi.edu/learn/brain/metals.html



—SANDIA Report on UV-LEDs.

Background

Water in Space?



<http://apod.nasa.gov/apod/ap070625.html>

The slide features a large background image of the International Space Station (ISS) in orbit above Earth's blue and white clouds. On the left side, there is a vertical strip of six small, numbered images (1-6) showing various water-related activities: 1. A child looking into a bowl of water. 2. A close-up of water droplets. 3. A child drinking from a cup. 4. A green container with water. 5. A child washing their hands. 6. A small globe of Earth.

Background

- Water Disinfection
- Primary Disinfectant
- Secondary Disinfectant
- U.S. NASA-EPA

This slide is similar to the one above, with the same vertical strip of six small images on the left. The main content area on the right contains the word 'Background' at the top and a bulleted list of four items: 'Water Disinfection', 'Primary Disinfectant', 'Secondary Disinfectant', and 'U.S. NASA-EPA'.



Problem Statement

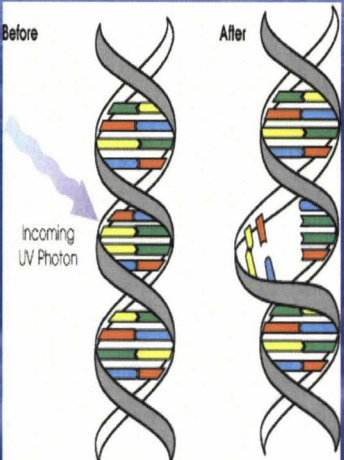
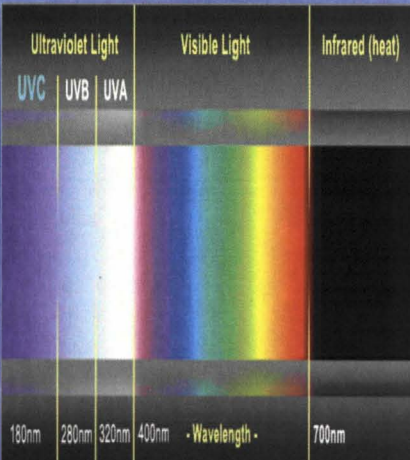
- There is the need for a safe, low energy consuming and compact water disinfection technology to maintain water quality for human consumption



Background

- Chlorination YES or NO?
- Metals
- Other....Chloramines, Ozone
- Ultraviolet Radiation?

■ UV Disinfection

Before After

Incoming UV Photon

Ultraviolet Light Visible Light Infrared (heat)

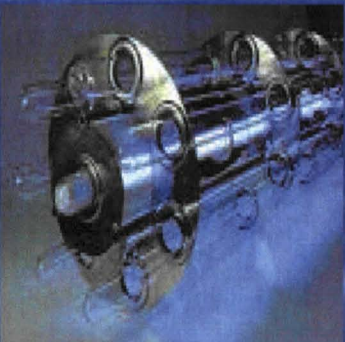

UVC UVB UVA

180nm 280nm 320nm 400nm - Wavelength - 700nm

http://www.canadianair-water.com/UV_Technology.html
<http://germfreeuv.com/uv-facts.html>

Background


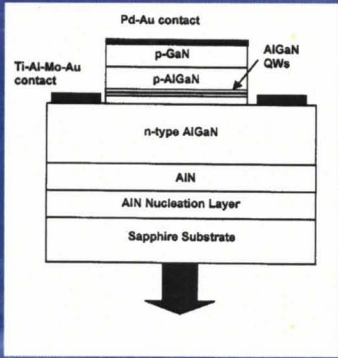
■ UV Disinfection

<http://www.awwa.org/publications/AWWAJournalArticle.cfm?itemnumber=30104>
http://qobizkorea.com/offer/offer_main.jsp?biz_type=...

Background

- UV-LEDs

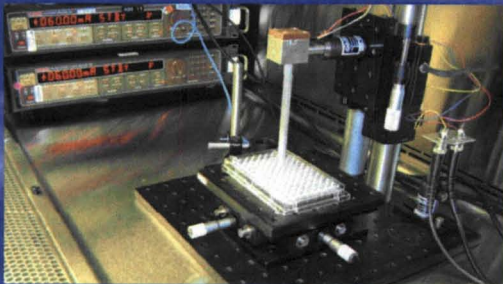



- <http://ledmuseum.home.att.net/leduv.htm>

SANDIA Report on UV-LEDs.

Background

- SANDIA Report 2005
- Escherichia coli ATCC 23229, high sensitivity to UV
- Escherichia coli ATCC 15596, medium sensitivity to UV



- Picture from SANDIA REPORT SAND2005-7245, page 28



Background

- Vilhunen et al. 2008
 - Escherichia coli* (k12)
- Hammamoto et al. 2007, and Mori et al. 2007
 - Vibrio parahaemolyticus*
 - enteropathogenic *Escherichia coli*,
 - Staphylococcus aureus*




Background

-*Escherichia coli* DH5 α

were reduced by greater than 5-log₁₀ stages within 75 min at 315 J/cm² of UVA

-*Salmonella enteritis*

was reduced greater than 4-log₁₀ stages within 160 min at 672 mJ/cm² of UVA




Background

Birmele et al., 2009


- *Sphingomonas paucimobilis*,
- *Pseudomonas aeruginosa*,
- *Burkholderia cepacia*,
- *Methylobacterium fujisawaense* and
- *Cupriavidus metallidurans*

3-log reduction in one hour of UVC exposure in a static test



Background

- UVA Disinfection



Ultraviolet Light			Visible Light	Infrared (heat)
UVC	UVB	UVA		
180nm 280nm 320nm			400nm	700nm
• Wavelength •				

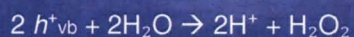
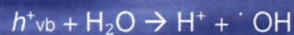
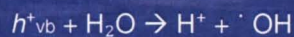
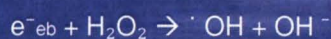
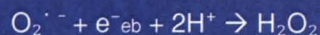
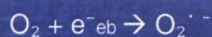
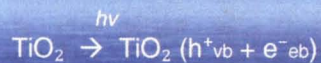
<http://www.thescienceofcreativity.com/794>

germfreeuv.com/uv-facts.html



Background

■ TiO_2



Silver, Ag

■ Silver has been used in:

- Water, vinegar, fruit juices, wine
- Dental amalgams, composites
- Topical creams, bandages, catheters, medical devices
- Polymers, ceramics, synthetic fabrics



Silver, Ag

■ Mechanisms of microorganism Inactivation:

■ Accumulates inside cells

■ Binds to:

- Cell wall/ membranes
- Proteins (-SH)
- DNA
- Electron donor groups




General Objective

- Design and test a reactor to prove the efficacy of a UVA-LED, TiO_2 , and nanosilver safe technology to sustain water quality for life support systems.


Microorganisms tested:

- MS2 Bacteriophage
- Pseudomonas aeruginosa*
- E. Coli*



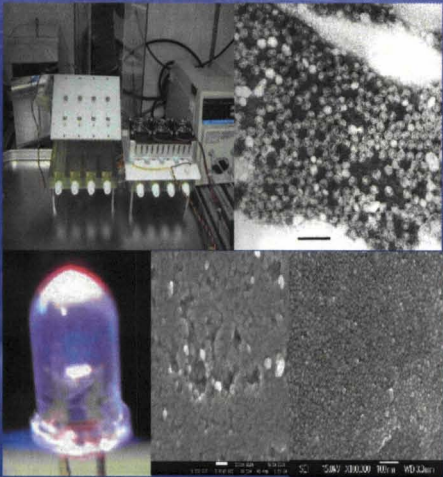
Experiment Design

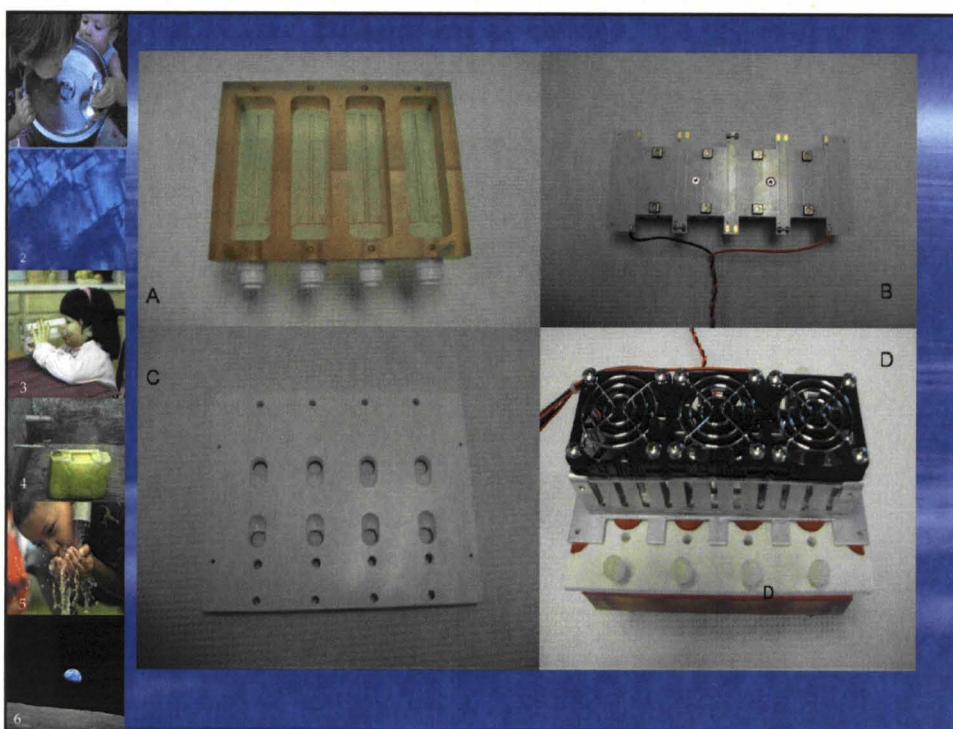
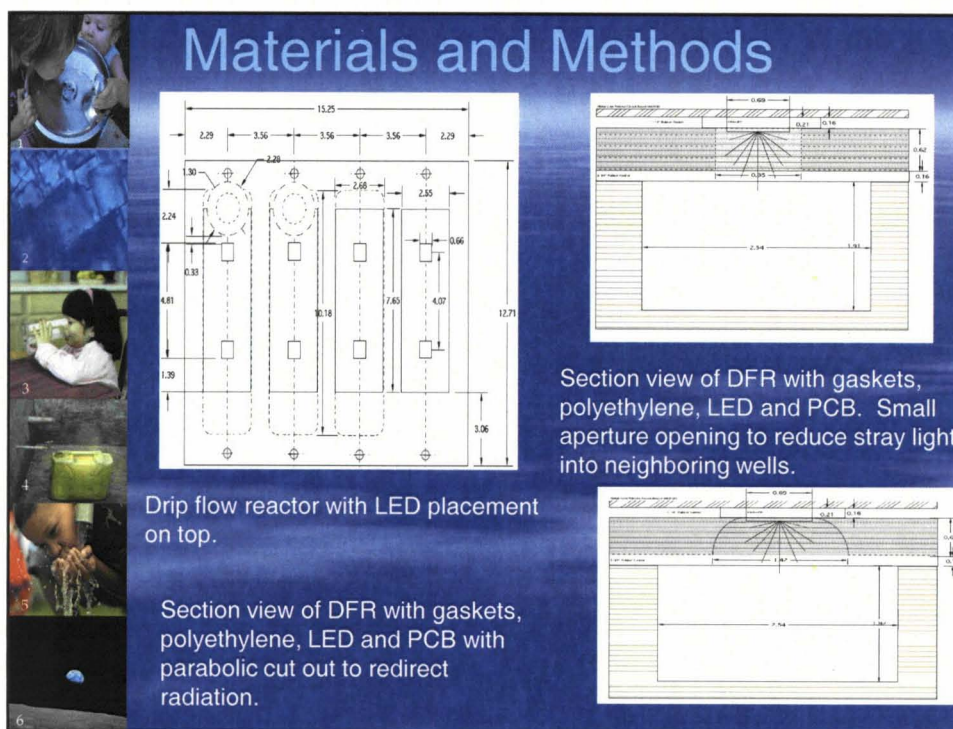
Experiment	UVA-LED	TiO ₂	Nanosilver
Treatment 1	X		
Treatment 2	X	X	
Treatment 3	X		X
Treatment 4	x	x	x



Materials and Methods

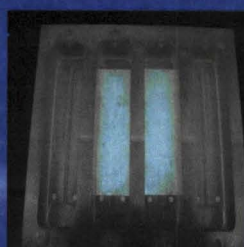
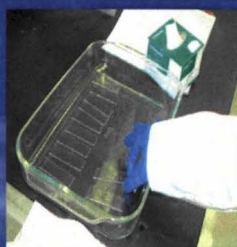
- Modified DFR
- UVA-LEDs
- TiO₂ coated glass slides
- Nanosilver





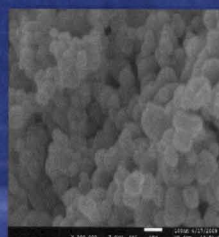
Materials and Methods

TiO₂ glass slides preparation was done by slurry deposition in a glass borosilicate slide (1x3 in).





Materials and Methods


■ Nanosilver




Materials and Methods












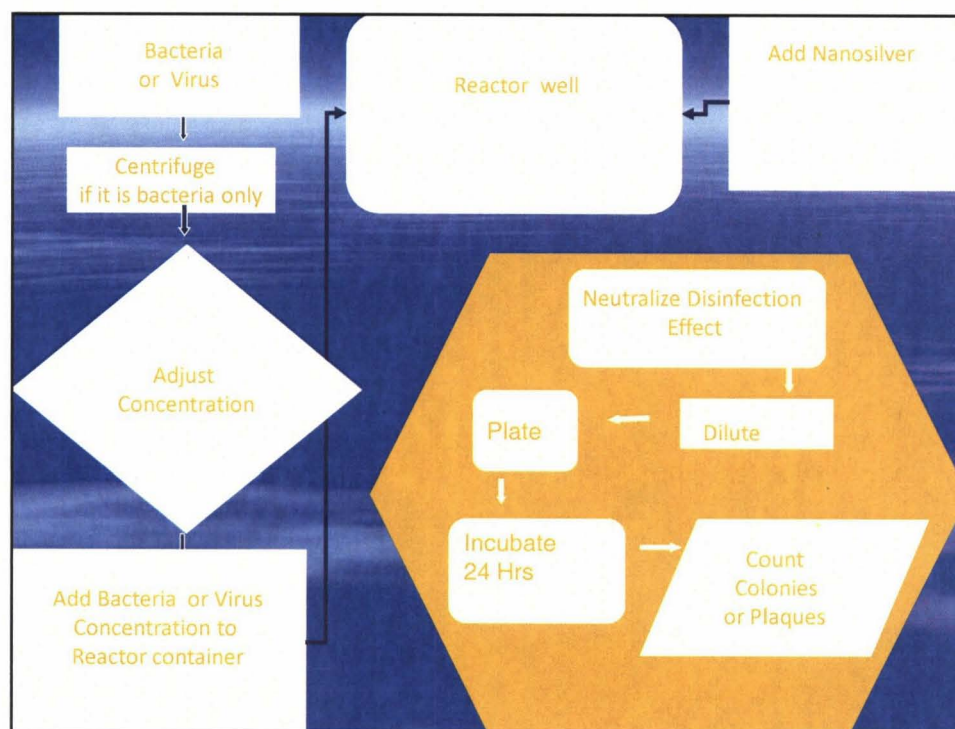
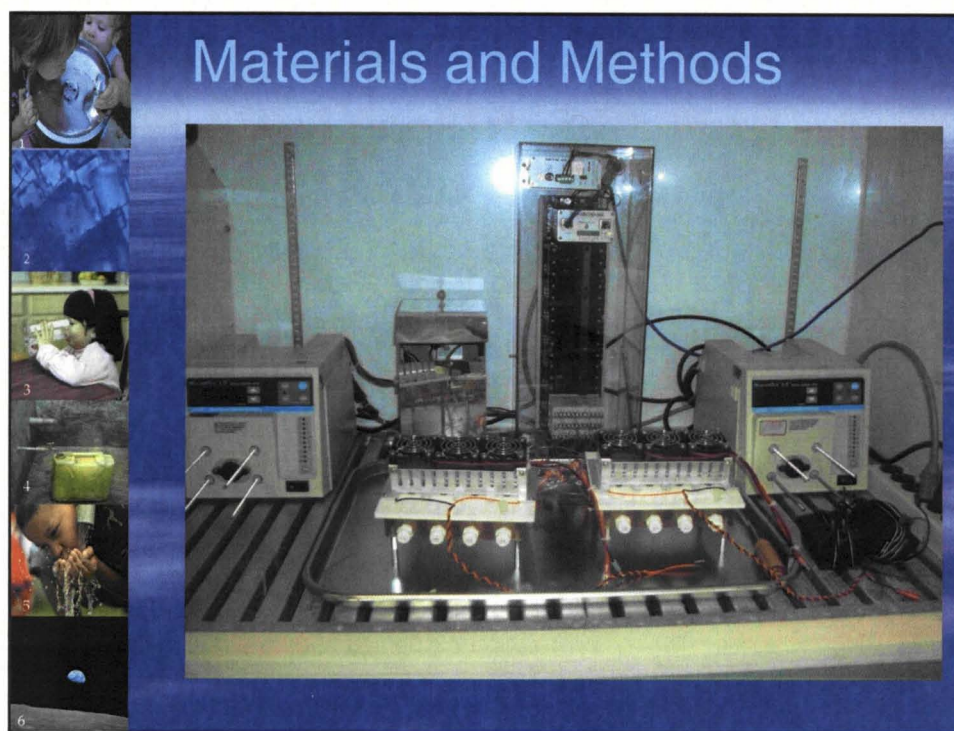
Areas of Opportunity

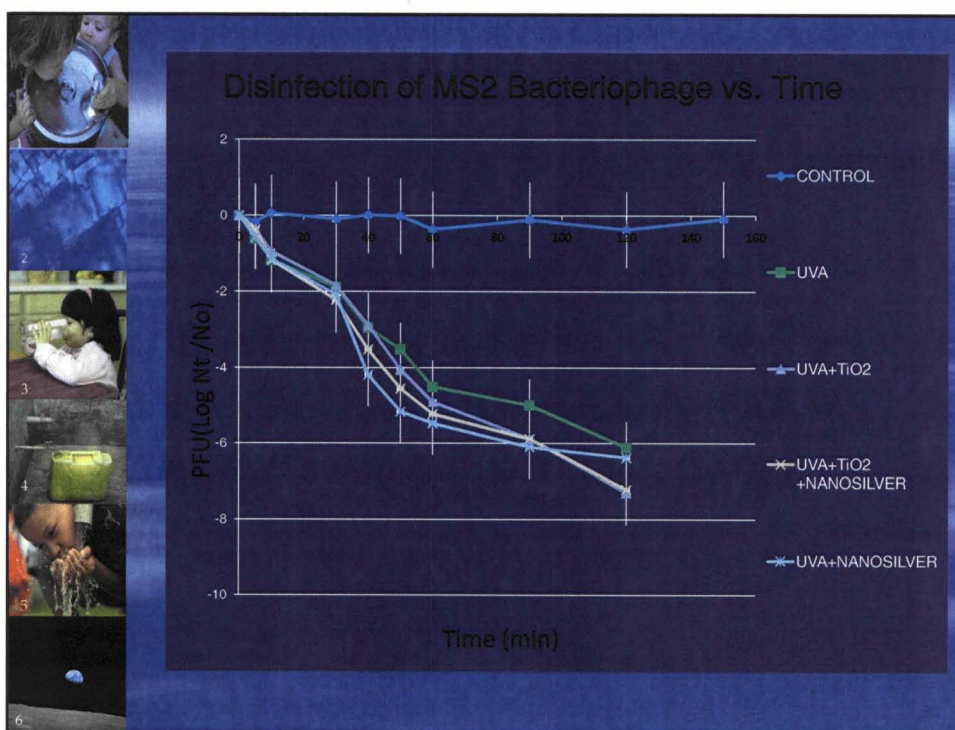
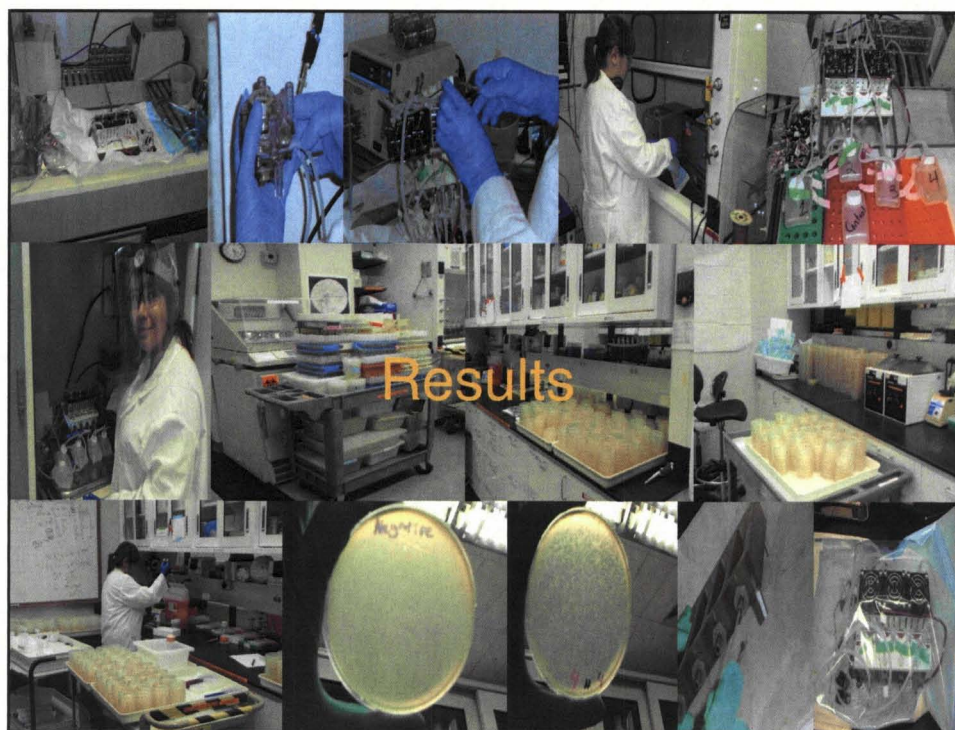
- TiO_2 coating
- Nanosilver application and quantification

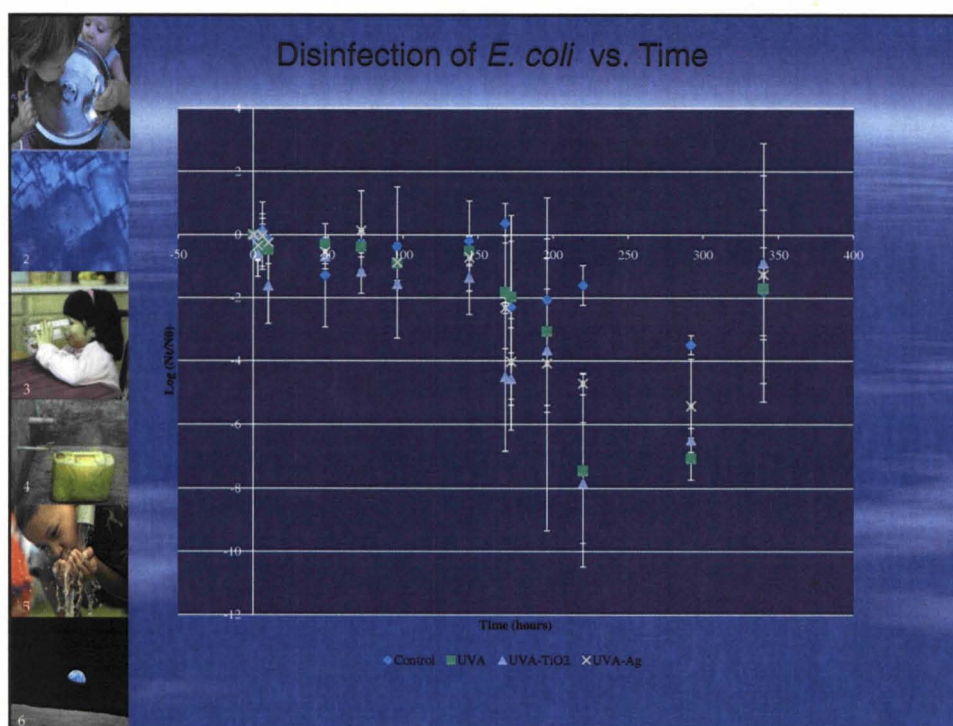
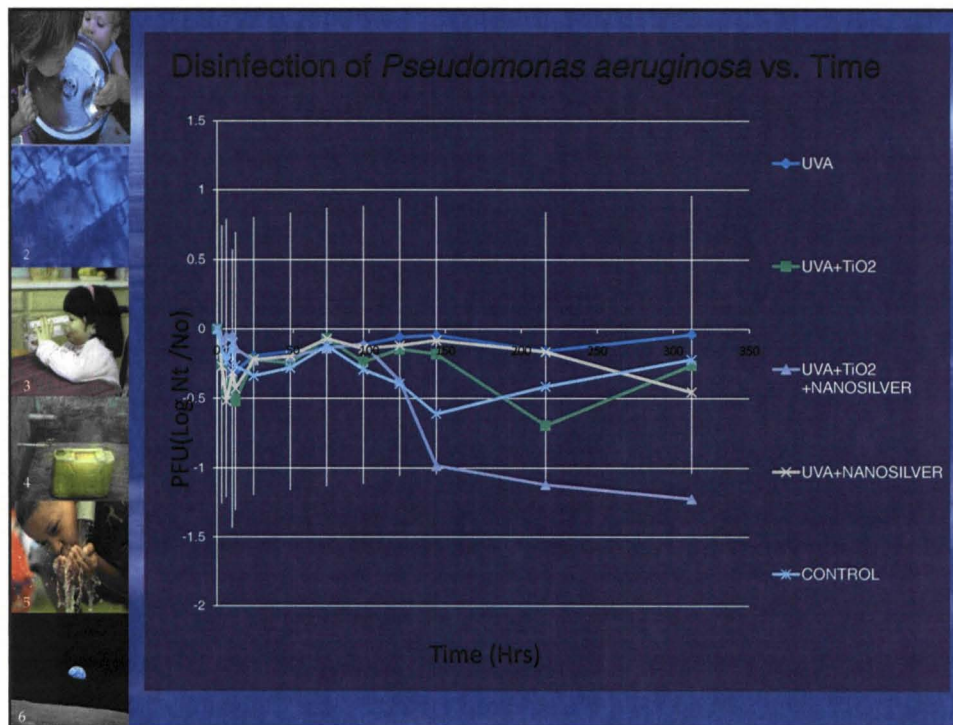














Conclusions

- The design of the reactor presents no overheating and a constant temperature. A good electrical and optical performance for a UV water treatment system.
- The assessment of this study shows that UVA-LEDs can be used as a good disinfectant in water for MS2 Bacteriophage. The log reduction was sufficient to meet US EPA standards as a secondary disinfectant for maintaining water quality control.



Conclusions

- This study has shown that at the conditions tested there is no inactivation of *Pseudomonas aeruginosa* and *E. Coli* and further testing at different conditions (specifically contact area and time of exposure) have to be performed to use UVA-LED as a secondary disinfectant to maintain water quality.



Further work recommended

- Other contact areas and longer times of exposure should be tested.
- Microorganisms:
-*Cryptosporidium parvum* oocyst
- Other research lines such as biocides and reactive oxygen species in the reactor.



Key point

UVLEDs are a viable disinfectant in water that should be further investigated to develop an optimized Water Technology for Earth and Space Applications




References

- 1.- US SANDIA National Laboratories. Final LDRD Report: Ultraviolet Water Purification Systems for Rural Environments and Mobile Applications. November 2005.
- 2.- Hammamoto et al. 2007; Mori et al. 2007; Vilhunen et al. 2008.
- IMAGES ON LEFT SIDE:
- 2.- apod.nasa.gov/apod/image/9909/water_jsc.jpg
- 3.- coep.pharmacy.arizona.edu/water/drink2.jpg
- 4.- www.ryanswell.ca/projects/images/Photo5_Page1
- 5.- imthi.com/.../2009/09/charity-water-honduras.jpg
- 6.- NASA Image: Earthrise over the lunar horizon, December 1968.



Acknowledgements

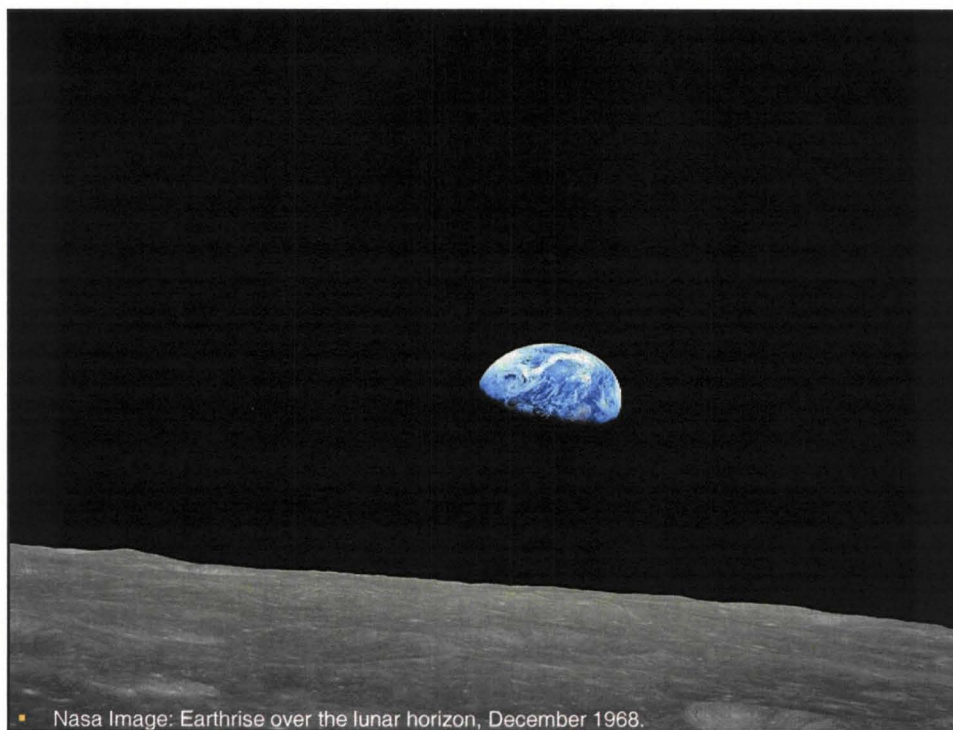


- NASA and NPP administered by ORAU.
- Michael S. Roberts, Raymond Wheeler, and Daniel Barta.
- KSC Education Office (Patricia Gillis, Lisa Valencia, Hortense Burt and Lesley Garner).
- Dynamac technical support staff and everybody in the LSSC contract.
- Paul Hintze, LaNetra Tate, Wenyan Li, Jackie Quinn, Lanfang Levine, Luz Maria Calle, Brenton Hicks, Kari Cezat and Carolina Ragolta.

Questions?



- earthfirst.com/tag/water/
- Nasa Image: Earthrise over the lunar horizon, December 1968.



■ Nasa Image: Earthrise over the lunar horizon, December 1968.